RESEARCH TRIANGLE INSTITUTE

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# BIOMEDICAL APPLICATIONS OF NASA SCIENCE AND TECHNOLOGY

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Quarterly Progress Report 2
15 September 1968 to 14 December 1968



Prepared for

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Washington, D. C. 20546

## Preface

This report covers the activities of the Research Triangle Institute's Biomedical Application Team during the period from 15 September 1968 to 14 December 1968. These activities were supported by the National Aeronautics and Space Administration under Contract No. NSR-34-004-056. This work was performed in the Engineering and Environmental Sciences Division of the Research Triangle Institute under the technical direction of Dr. James N. Brown, Jr. Other team members were Ernest Harrison, Jr. who participated full-time and Dr. F. T. Wooten who participated three-quarter time on the project.

Medical research consultants at the participating medical schools who contributed to the project are Dr. E. A. Johnson, Professor of Cardiac Pharmacology, Duke University Medical Center, Durham, North Carolina; and Dr. G. S. Malindzak, Jr., Associate Professor of Physiology, Wake Forest University, Bowman Gray School of Medicine, Winston Salem, North Carolina. Institutions with which the Biomedical Application Team maintains liaison are Duke University Medical Center, Durham, North Carolina; Bowman Gray School of Medicine, Wake Forest University, Winston Salem, North Carolina; the Dental Research Center and the Medical School of the University of North Carolina, Chapel Hill, North Carolina; North Carolina State University, Raleigh, North Carolina; New York University Medical Center, New York, New York; Veteran's Administration Hospital, Durham, North Carolina.

Abstract

During the period 15 September 1968 to 14 December 1968, the NASA-supported Biomedical Application Team at the Research Triangle Institute has identified 6 new problems, performed significant activities on 15 of the active problems identified previously, performed 5 computer searches of the NASA aerospace literature, and maintained one current awareness search. As a partial result of these activities, one technology transfer was accomplished. As a part of continuing problem review, 13 problems were classified inactive.

Activities during the quarter involved all phases of team activity with respect to biomedical problems. As has been observed in preceding years, it has been exceedingly difficult to arrange meetings with medical investigators during the fourth quarter of the calendar year. This is a result of a combination of factors. Teaching requirements, submission of grant applications and holidays are the most significant factors involved. As a result, the numbers of new problems identified and of transfers and potential transfers are relatively low during this quarter. Most of our activities have thus been directed toward obtaining information related to problems already identified.

Consequently, during the next quarter we will follow up on these activities with the expectation that transfers will be accomplished on a number of them. In addition, the normal availability of researchers to the team is expected to be restored during this quarter, permitting an increase in new problem identification activities as well as follow-up with other researchers on old problems. Another activity scheduled for the next quarter is consultation with several interested biomedical equipment manufacturers to explore means of effective interaction between the Biomedical Application Team and these companies.

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## 1.0 Introduction and Summary

This project has as its objective the transfer of scientific and technological results of the nation's aerospace programs into the biological and medical sciences. To facilitate the transfer of scientific and technological information to clinicians and medical researchers, the National Aeronautics and Space Administration supports three multidisciplinary Biomedical Application Teams. The methods used by the application teams are: (1) to identify problems and needs existing in the medical field which appear to be "solvable" by the application of aerospace science and technology, (2) to identify the specific technologies or concepts which may lead to solutions of these problems, and (3) to document these transfers of science and technology so as to achieve maximum utilization of the results of the program. A further objective of this program is to contribute to an increased understanding of the elements involved in the information and technology transfer process in order to perform the transfer process more efficiently and effectively. This understanding is primarily gained as a result of the identification of difficulties which impede transfer efforts in specific practical biomedical problems and the observation of those elements which contribute to efficiency and speed in the transfer process. The teams are to apply this increased understanding of the transfer process to their field operations so as to provide a more effective interface and information channel between the life sciences and the physical sciences in general.

To achieve these objectives, members of the application team discuss with researchers and clinicians at the participating medical institutions those problems that are being encountered in biological and medical research. These meetings and discussions are coordinated and, to a great extent, given direction and purpose by consultants who are staff members at the medical institutions. The team seeks to understand fully both the nature of the problems and how they affect the progress of research or hinder

patient treatment and care. Following these discussions, the team members specifically identify each discrete problem and translate these problems into the terminology of the engineering and physical sciences.

When appropriate, a biomedical problem abstract, a concise statement of the problem, is prepared and disseminated through the Technology Utilization Division of NASA to the NASA research centers and other participating organizations in the space program to solicit information pertinent to a solution. At the same time, the team employs the services of NASA Regional Dissemination Centers, such as the Science and Technology Research Center located adjacent to the Research Triangle Institute, to search the computerized aerospace information bank maintained by NASA's Technology Utilization Division. All information obtained from information searches, biomedical problem abstract responses, or the experience of application team members and consultants is then evaluated. In addition to the team members, the medical consultants plus the researchers and clinicians who originated the problems contribute to the evaluation process. Finally, the Biomedical Application Team encourages and, when possible, aids researchers in the application or adaptation of technology identified by these activities.

Section 2.0 of this report contains a discussion of the transfers of technology made by the Research Triangle Institute's Biomedical Application Team during this quarter. Section 3.0 enumerates the new problems which have been identified. Section 4.0 details significant activities of the team on previously identified problems. The problem review in Section 5.0 indicates those problems which have been classified as inactive, along with the reason for such classification.

Section 6.0 summarizes the information searching activities of the team, which include computer searches of the NASA information banks, manual searches of the NASA information banks, and a variety of miscellaneous searching procedures. Other activities of the team are presented in Section 7.0, and the financial summary for the quarter is tabulated in Section 8.0. Appendices A through E contain: (1) computer evaluation

reports on all computer searches conducted during the quarter, (2) a listing of transfer criteria, (3) biomedical problem abstract response evaluations on all suggestions which have been received or evaluated during the quarter, (4) a bibliography of documents supplied to researchers, and (5) abbreviations.

## 2.0 Technology Transfers

### 2.1 Introductory Information

The criteria which have been used to establish technology transfers are listed in Appendix B. The documentation of technology transfers contains the following information: (1) Description of Problem, (2) Description of Solution, (3) Successful Searching Method, (4) Source of Solution, (5) Benefits to be Derived from Transfer, (6) Status, (7) Cost of Biomedical Application Team Activities to Date, and (8) Elapsed Time to Complete.

The transfer documented here represents a solution to the following problem:

WF-63 "A Low Cost, Swallowable, pH Sensing Telemetry Capsule"

### 2.2 Transfer Documentation

WF-63

A Low Cost, Swallowable, pH Sensing Telemetry Capsule

Dr. T. F. O'Brien, Jr., Bowman Gray School of Medicine

Description of Problem:

Dr. O'Brien wishes to measure pH in the gastrointestinal tract. In order to make this measurement, it is felt necessary to place a sensor into the gastrointestinal tract to measure pH. Perhaps the simplest solution to making such a measurement is the use of an endoradiosonde. Using this technique, a pH sensor is placed in a small capsule with a radio transmitter. The capsule is then swallowed by the patient, and external antennas are used to pick up the transmitted signal, which contains the pH information, as the endoradiosonde traverses the gastrointestinal tract. The endoradiosonde is to be used in a program to determine the effectiveness of antacids and anticholinergic drugs in the gastrointestinal tract.

Description of Solution:

A commercially available endoradiosonde manufactured by the Telefunken Corporation of West Germany has been identified as being applicable to this problem. This company has as its United States distributor, Medintron Corporation of America. Performance characteristics and size information were obtained from Medintron. The researcher has evaluated the unit and found it to be completely suitable for his purposes. Pricing information has been obtained, and the researcher is considering means of obtaining financial support for this program.

Successful Searching Method:

The solution to this problem was identified by the NASA-supported Biomedical Application Team as a result of information searching in the commercial literature.

Source of Solution:

Telefunken Corporation of West Germany.

Benefits to be Derived from Transfer:

Excess acid secretion can be controlled by two mechanisms: (1) antacid therapy; i.e., Alka Seltzer, Digel, and other such preparations, and (2) anticholinergic drugs; i.e., cholinergic blocking agents. Antacids function to neutralize acids secreted by the tissue in the stomach. Anticholinergics act to prevent the secretion of acids by the tissue in the stomach. The relative effectiveness of many of the newer antacids and anticholinergics has not been clearly determined. The pH capsules will permit monitoring the actual pH of local areas of the stomach in response to a variety of antacids and anticholinergics. This will lead to a determination of the efficacy of these drugs in cases of hyperacidity.

Treatment of hyperacidity is of importance, not only because of the discomfort associated with it, but also because hyperacidity is clinically associated with gastric and duodenal ulcers.

Current Status:

The researcher is exploring means of obtaining funding to support this research project.

Cost of Biomedical Application Team Activities to Date:

Approximately $700.

Elapsed Time to Complete:

10 months.

## 3.0 New Problems

During the preceding reporting period, seven new problems have been discussed with medical investigators. Problem statements for these seven new problems have been prepared and are presented herein. One problem, DU-36, "Cervical Cancer Diagnosis," has been previously introduced but no problem statement had been formulated at the time.[1] For this reason, it is included in the new problem section instead of the previously identified problem section.

### DU-36

### Cervical Cancer Diagnosis

### Dr. W. W. Johnston, Duke University Medical Center

Description of Problem:

The general area of interest is detection of cancer. The specific problem is detection of cancer of the cervix. Cervical cancer is detected by scraping cells from the neck of the womb and smearing them on a microscope slide. The malignant cells have a different shape from healthy cells when observed under the microscope. All women over 20 should have this test annually. If detected early, the disease is curable. If not, the disease is fatal.

The problem arises because this test is manual, and the large number of samples tested in Dr. Johnston's laboratory is at present burdensome. The researcher desires a method of automatically screening the samples.

Status:

Information gained from a previous search (#817, Image Processing) was applied to this problem.

A search of the commercial literature disclosed an instrument, to be produced shortly, that is designed for this application. The information is now being evaluated by the researcher.

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[1] Biomedical Applications of NASA Science and Technology, Contract No. NSR-34-004-035, Monthly Status Report, July 15, 1968 through August 14, 1968

DU-38

## Analysis of Electrophoretic Patterns of Serum

Dr. Susan C. Dees, Duke University Medical Center

Description of Problem:

One of the basic clinical tools for diagnosis of disease is electrophoresis of serum (watery portion of blood after coagulation). Electrophoresis may be defined as the migration of charged colloidal particles in an electric field. It is possible to use this technique for diagnosis of various conditions including infection and susceptibility to infection.

Electrophoresis separates the serum into four components because each component migrates at a different rate in the electric field. The optical density of each component is recorded as a function of distance of migration using a densitometer. This curve is used as a measure of the concentration of each component in the serum by determining the area under the portion of the curve representing each component.

Dr. Dees wants to know if more information than just the area is contained in the curve. This would enhance the diagnostic technique. For example, it would be desirable to know if two curves with the same area but different shapes indicate different physiological conditions.

Thus, the researcher wants a mathematical analysis technique that extracts the maximum information from a continuous function.

Status:

A search of the open literature is being performed to see if similar work has been done. If not, a search of the NASA data bank will be made to determine the appropriate mathematical analysis techniques.

DU-39

Miniature Pediatric Pulse and Respiration Rate Monitor

Dr. Susan C. Dees, Duke University Medical Center

Description of Problem:

The area of general interest is allergy in children. Dr. Dees is interested in both the research and clinical aspects of pediatric allergy. The specific area of interest is asthma. Asthma affects from 2 to 5 per cent of the population and is characterized by recurrent periods of severe respiratory difficulty. Between attacks the patient is free of symptoms.

It is desirable to have an early warning of the onset of an asthmatic attack. This would be helpful in treating known asthmatic patients and also for diagnosis. Asthmatic attacks usually occur at night and affect both pulse and respiration rate. The researcher desires a small pulse and respiration rate monitor that can be worn by children at night. The monitor would telemeter the information to a bedside receiver.

Status:

Information from the computer search #679, Biotelemetry, for problem DU-9, "A 4-Channel Telemetry System to be Used in Experiments with Dogs" and search #1469, Oxygen Tension in Tissue and Biotelemetry, for problem NCSU-4, "Telemetry from Wood Ducks in Natural Environment," was applied to this problem. In addition, a search of the commercial literature is being conducted.

DU-40

## Differential Pressure Transducer for Cardiac Catheter

Dr. Joseph C. Greenfield and C. Frank Starmer
Duke University Medical Center

Description of Problem:

The general subject of heart disease is receiving a major research effort. One method for diagnosis of heart disease is to study the pressure and flow relationship in the arteries. One of the few techniques available for this study is to insert a catheter into the artery and to measure pressure at two points along the catheter. From this measurement the pressure and flow can be determined. Problems with this technique involve the pressure transducer.

The researcher desires a transducer to measure the differential pressure between two points in the human artery. Improvements desired over existing techniques include higher frequency response and greater resolution.

Status:

Information obtained in search #686, Pressure-Volume Measurement in the Heart, for problem DU-1, "Techniques for Calculating Left Ventricular Volume from Biplane Cineradiographs" and search #1128, Blood Flow Meters, for problem WF-53, "Means of Obtaining the Velocity Spectrum of Blood Flowing in Arteries and Veins," is being applied to this problem. NASA Tech Brief 67-10669 "Ultraminiature Manometer-Tipped Cardiac Catheter" has been delivered to the researcher. A search of the commercial literature is being conducted.

NCSU-4

Telemetry from Wood Ducks in Natural Environment

Dr. F. Eugene Hester, North Carolina State University

Description of Problem:

Dr. Hester is interested in the population management of waterfowl. In particular, he is interested in the wood duck which has the largest nesting population in North Carolina. It is also the most popular among hunters in terms of numbers killed.

The particular area of interest in population management of wood ducks is the nesting behavior. Dr. Hester is studying the type of natural cavity used by the ducks. He also wants to know if the ducks will move to man-made boxes when available. Further information is desired on the movement and mobility of the brood.

In order to accomplish this study, the researcher requires a miniature transmitter for tracking the ducks during the nesting period. Approximately a one-mile range is required as well as a portable receiver.

Status:

Information from the computer search #679, Biotelemetry, for problem DU-9, "A 4-Channel Telemetry System to be Used in Experiments with Dogs," was applied to this problem. In addition, the search was brought up to date. The Bioinstrumentation Advisory Council was contacted, and its biotelemetry information was delivered to the researcher. The computer search has been delivered to Dr. Hester.

NCSU-5

Oxygen Content of Ichthyological Ovarian Fluid

Robert E. Stevens, North Carolina State University

Description of Problem:

One of the most popular fish for fresh water reservoirs is the striped bass. With the rapid increase in the number of sport fishermen and the number of available reservoirs, the interest in this fish has increased. The striped bass requires about 40 miles of river for spawning because the eggs drift with the current instead of remaining fixed in a bed. Because many reservoirs do not have an adequate spawning area, government hatcheries often supplement the natural supply.

One of the difficulties encountered by the hatcheries is the short "ripe" period of the eggs, which is the time between ovulation and spawning. The reasons for this short period (1 hour) are being explored. Mr. Stevens wants to determine if the reason is lack of oxygen in the ovarian fluid. He requires an oxygen sensing electrode that can be placed in the ovary. Telemetry is not required initially but would be desirable at a later date.

Status:

Information from the computer search #1135, Oxygen Tension in Tissue, for problem WF-35, "Oxygen Tension in Tissue," was applied to this problem. In addition, a search of the commercial literature was performed. Both types of information were delivered to the researcher.

WF-62

## An Extremely Thin Pressure Transducer to Measure the Pressures Exerted on Tissue by Support-Type Hosiery

Dr. H. D. Green, Bowman Gray School of Medicine

Description of Problem:

One of the researchers at Wake Forest has been asked by a leading textile manufacturer to undertake a program to evaluate the pressure effects of support-type hosiery on the vascular circulation in human legs wearing such stockings. One of the first requirements is to determine the magnitude of the compressive force exerted by the stockings on the leg. A very thin pressure transducer is needed for placement at various points between the stocking and the leg so that the pressure can be measured. Small size, particularly extreme thinness, is required so that introduction of the transducer itself will not increase the measured pressure by essentially increasing the leg volume. The pressure to be measured is, of course, relatively small so that a sensitive transducer is required.

Status:

A manual search of the commercial literature has revealed a thin capacitive type transducer available from Spitz Laboratories, Inc. which may possibly offer a solution to the problem. The manufacturer has been contacted to obtain additional information to permit evaluation of the usefulness of the transducer in this particular application. In addition, manufacturers of pressure sensitive paints have been contacted to determine the feasibility of using such paints in connection with the problem.

WF-63

A Low-Cost, Swallowable, pH Sensing Telemetry Capsule

Dr. T. F. O'Brien, Bowman Gray School of Medicine

This problem was identified during this quarter. However, since a solution has also been identified during the quarter, it is discussed in Section 2, Technology Transfers.

## 4.0 Activities on Previously Identified Problems

This section describes the activities of the Biomedical Application Team during this quarter on active problems which were identified prior to this quarter. In addition, follow-up action on potential transfers and transfers which were identified prior to this quarter is discussed.

### DU-37

### Localized Cooling of Heart Muscle

### Dr. Madison S. Spach, Duke University Medical Center

Description of Problem:

One method of studying heart function is to study the mechanical contractile process while observing the progress of electrical activity over the surface of the heart wall. These observations are more informative when coupled with selective, local inactivation of small sections of the heart wall. Local inactivation can be accomplished by cutting the muscle, but an improved technique would be to locally cool the individual muscles.

A probe capable of cooling a small (3mm x 3mm) section of the heart wall to 15°C is desired. Dr. Spach has previously tried a liquid coolant, but this has been unsatisfactory because of the bulk of the input and output tubes. A small probe with miniature leads is required.

Status:

The results of computer search #1370, Physiological Cooling Probe, was delivered to the researcher. A number of articles relating to thermoelectric cooling have been requested. A search of the commercial literature disclosed both thermoelectric coolers and liquid coolant probes. Dr. Spach is at present studying this information. All the commercial devices will require some modification.

UNCD-15

A Device to Measure Looseness of Teeth

Dr. D. L. Allen, Dental Research Center, University of North Carolina

Description of Problem:

Dr. Allen is pursuing a research project with a primary interest in the mechanisms involved in bone growth and resorption. It has been clinically recognized for a number of years that the degree of mobility of teeth in patients varies with time. The causes for this variation in looseness or mobility of the teeth are not accurately known. Accurate measurement of the looseness, or the mobility, of teeth is extremely desirable to permit a better understanding of this phenomena.

Many efforts have been made by various researchers to quantitate the degree of mobility of teeth. A number of methods have been evolved to make this measurement. The methods are not simple, however, and require a considerable amount of instrumentation and time. Generally, these methods have involved the application of a force against a tooth with a measurement of the corresponding displacement of the tooth with respect to another tooth or group of teeth in the mouth. An accurate and easy-to-use method of determining the mobility of teeth is desired.

Status:

A manual search of the aerospace literature has been previously conducted and yielded little useful information. State-of-the-art engineering techniques have been examined to determine if any of the present methods of force and displacement measurement now in use can be modified or adapted to obtain a solution to this problem. During this quarter, a full retrospective search of the aerospace literature has been conducted by the North Carolina Science and Technology Research Center. The search, Tooth Mobility Testing No. 1409, has been received and is being evaluated.

UNCD-18

## Methods of Determining if Tooth Roots are Attached to the Jaw Bone Structure

Dr. R. M. Nelson and Dr. G. Helmers, University of North Carolina Dental School

Description of Problem:

It is not unusual for the roots of a tooth to become rigidly attached to the jaw bone structure. When this occurs, it is extremely difficult, if not impossible, to bring about orthodontic correction in the position of the teeth. It would be extremely valuable for the orthodontist to be able to determine beforehand if any individual tooth, upon which he wished to exercise correction in position, was firmly attached to the jaw bone structure. If the tooth is firmly attached, before orthodontic correction can be accomplished it is necessary to break the tooth loose from the jaw bone structure.

Status:

During the previous quarter, initial problem specification was completed. During this quarter, search bibliography No. 1409, Tooth Mobility Testing, was made of the aerospace literature. This search which is a full retrospective search of the NASA information banks was run for application to this problem as well as to UNCD-15 because of the similarity of the subject matter of these two problems. The search is presently being evaluated.

UNCD-24

# An Adhesive to Glue Brackets to Teeth

Dr. R. M. Nelson and Dr. G. Helmers,
University of North Carolina Dental School

## Description of Problem:

In order to apply force to a tooth, it is necessary to attach to the tooth a small bracket to which force can be applied. Presently, this bracket is attached to a band of metal which completely encircles the tooth and is very carefully fashioned to fit each individual tooth. This is a very time-consuming and expensive part of the procedure.

It would be extremely desirable to eliminate this custom-fitting of the metal band to each individual tooth, since this would result in a great reduction in the difficulty of applying orthodontic procedures and would no doubt result in a corresponding decrease in the cost of such procedures. The average size of the base of the brackets which are attached to teeth is in the order of 6 $mm^2$. These brackets must resist biting pressures as high as 300 psi when the patient is biting hard substances. In addition, the adhesive must also be able to withstand the very corrosive nature of the mouth fluids and must bond to tooth enamel with great strength.

## Status:

A full retrospective search of the aerospace literature was conducted during the previous quarter to determine if information existed in the NASA literature on a possible contact adhesive which could be used in this application. The search Contact Adhesives, Bibliography No. 1350, was evaluated during this quarter. None of the information found as a result of the search was of value in this particular application. As a further effort on obtaining a suitable adhesive, several commercial cements, including Eastman 910, were investigated for this application. Unfortunately, none of the adhesives investigated to this date have had the necessary characteristics of rapid setting, resistance to moisture, strength, and ease of application.

UNCD-25

## A Miniaturized Electrical System to Shock the Tongue of Patients When It is Pressed Against the Rear of Their Teeth

Dr. R. M. Nelson and Dr. G. Helmers,
University of North Carolina Dental School

Description of Problem:

This problem is closely related to the behavior pattern described in UNCD-17, "A Method of Measuring Tongue-Lip Pressures on the Teeth." When children acquire the habit of pressing against the rear of their teeth with their tongue, they persist in doing it unconsciously over long periods of time and cause movement of the teeth. This results in an improper spatial configuration of the mouth which is structurally undesirable and cosmetically unappealing. Some means of training children to refrain from this behavior pattern is needed. The researchers have indicated that their choice would be some means of shocking the tongue when it is pressed against the rear of the teeth and exceeds a certain predetermined pressure. This particular approach would, of course, require an extremely small device. Other approaches which could achieve the correction in behavior pattern are welcomed.

Status:

Initial problem specification has been completed, and several attempts have been made to formulate a search strategy which would permit obtaining useful information from the NASA information banks. As a result of several trials, a search has just been completed for the Research Triangle Institute's Biomedical Application Team by the North Carolina Board of Science and Technology Research Center on the subject of aversion therapy. This search was conducted to reveal methods employed by investigators in the past in bringing about behavioral changes in subjects. By screening the various techniques employed, it is hoped that a technique useful in this particular problem will be identified. The search has just been completed and will be evaluated during the following quarter.

WF-3

Prosthetic Valve for Urinary Tract

Dr. W. S. Montgomery, Bowman Gray School of Medicine

Description of Problem:

A number of different injuries and diseases can result in loss of control of urinary function. Victims of congenital defects, neurogenic bladder diseases, stroke, and multiple sclerosis, as well as war and automobile accident casualties, frequently experience bladder and urethral malfunctions. These malfunctions usually involve an inability to contract the muscles in the bladder wall or an inability to relax muscles which close the urethra; i.e., the passage through which the bladder is emptied. This condition generally results in gradual deterioration of the bladder, infections of the urinary tract, and in some cases damage to the kidneys and subsequent death. This condition is the most frequent cause of death of paraplegics.

In treating patients who cannot control urinary function, it is important that the bladder be allowed to fill and then be emptied rapidly every 3 to 4 hours. This periodic functioning allows the muscles of the bladder to be exercised and, as a result, to remain healthy. One approach that has been taken is to attach electrodes to the bladder muscles so that contraction of the bladder can be electrically induced by the patient. This electrical stimulation unfortunately also induces contraction of other muscle groups -- i.e., sphincters -- which close the urethra. As a result, fluid pressure inside the bladder becomes dangerously and painfully high.

A valve which can be implanted in the urethra and can be controlled by the patient is needed to successfully treat the loss of urinary function. In cases where bladder muscle is healthy when the valve is implanted, the bladder would contract when the valve is opened without

stimulation due to the inherent elasticity of healthy muscle tissue. If bladder muscle deterioration has occurred, electrical stimulation can be used simultaneously with opening of the valve without causing excessive internal pressure.

Status:

As was reported in the last quarterly report, a prototype experimental valve has been constructed by the Research Triangle Institute. During this quarter, initial laboratory testing of the device has been completed. The testing indicated that the device can fulfill all the performance requirements of this problem. The prototype valve is not itself suitable for implantation in an animal; therefore, to test the valve in actual operating conditions it is necessary to fabricate a valve suitable for implantation. Efforts have been made during this quarter to identify means whereby the valve could be fabricated. Dr. Quentin Hartwig and Mr. L. S. Wilson of the Biological Sciences Communication Project of the George Washington University suggested, as a result of their contacts with the National Bureau of Standards, that the Research Triangle Institute's Biomedical Application Team contact the National Bureau of Standards for assistance in this particular problem. Personnel at the National Bureau of Standards were contacted to determine what assistance could be given to the Biomedical Application Team in this case. Personnel at the National Bureau of Standards were very cooperative in discussing the various aspects of the problem. Their recommendations of a silastic rubber as the material to be used in fabrication of the device, reinforced our choice of materials. Currently, investigations are still underway to obtain a means whereby a valve suitable for implantation can be fabricated.

WF-13

## Radiation Detector for In Vivo Measurement of Absorbed Dose

Dr. D. D. Blake, Bowman Gray School of Medicine

Description of Problem:

This problem involves the measurement of local dosage in radiation therapy and treatment. Essentially, a small direct reading intracavitary dosimeter for use in radiation therapy is needed. This would permit the making of in vivo measurements of dose rate to various anatomic sites in patients undergoing radiation therapy. In the past few years, this development has consisted primarily of integrating systems such as glass beads or the thermoluminescent dosimeters. These require placement of tiny dosimeters within the tissues for a period of time during exposure to radiation, then removal of the dosimeters and calculation of the amount of exposure received. Primary disadvantages of such methods are large size, very low response, delayed readout, and limited flexibility. The major advantages of using a solid state radiation dosimeter are its small size, high sensitivity to radiation, rapid response, simple immediate readout, and flexibility. It will permit actual dose rates to be available during treatment which would permit alterations in the treatment as indicated.

Status:

As discussed in the previous quarterly report, the Biomedical Application Team is continuing to render assistance to the researchers in obtaining the instrumentation necessary to use the semiconductor radiation probe which was obtained from Solid State Radiation, Inc. A special charge amplifier and power supply developed by Solid State Radiation, Inc. for use with their probes have been received. Initial test and check-out by the researchers have been completed, and procedures are being formulated for use of the solid state radiation probe in the

research program of the medical investigator. Front and rear photographs of the charge amplifier are shown in Figures 1 and 2. Figure 3 is an overall view of the instrumentation showing the biomedical radiation probe connected to the charge amplifier along with the power supply and a counter which is used as the output device. The probe is in a cylinder used for external calibration purposes. Figure 4 is a close-up view of an x-ray phantom which is being used in preliminary tests with the equipment. The solid state radiation detector is shown attached to the surface of the x-ray phantom with a piece of adhesive tape. For internal measurements, the x-ray phantom is segmented, as can be seen in the photograph, so that the probe can be inserted internally into the phantom to permit measurements to be made at internal sites within the phantom. Figure 5 shows the entire setup with the biomedical radiation probe attached to the phantom, the charge amplifier, the power supply, and the counter.

WF-31

## A Servo-Controlled System to Measure the Partial Pressure of Oxygen and Carbon Dioxide in Expired Gases and to Control the Operation of Respirators

Dr. R. A. Kemp and Dr. J. H. Meredith,
Bowman Gray School of Medicine

Description of Problem:

A control system for respirators is desired which can control both the rate of respiration of a patient and also the volume of air supplied to the patient during each breath. At least two types of patients would benefit from such a device. The first involves the use of a respirator on a patient following extensive surgery or a patient in the intensive care unit when the patient's lungs are either not operating efficiently or when they impose too great a workload on the patient.


Figure 1 – Charge Amplifier, Front View

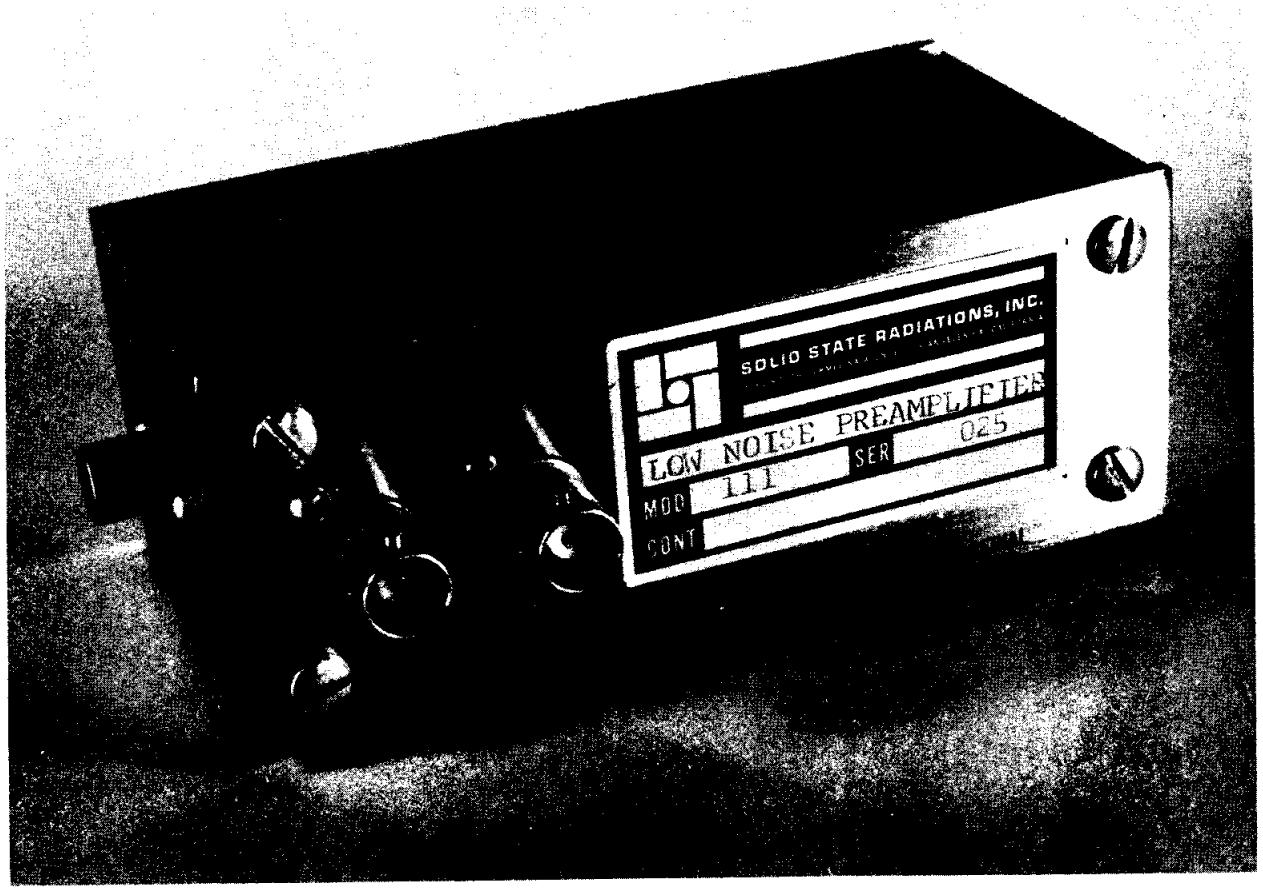



Figure 2 — Charge Amplifier, Rear View

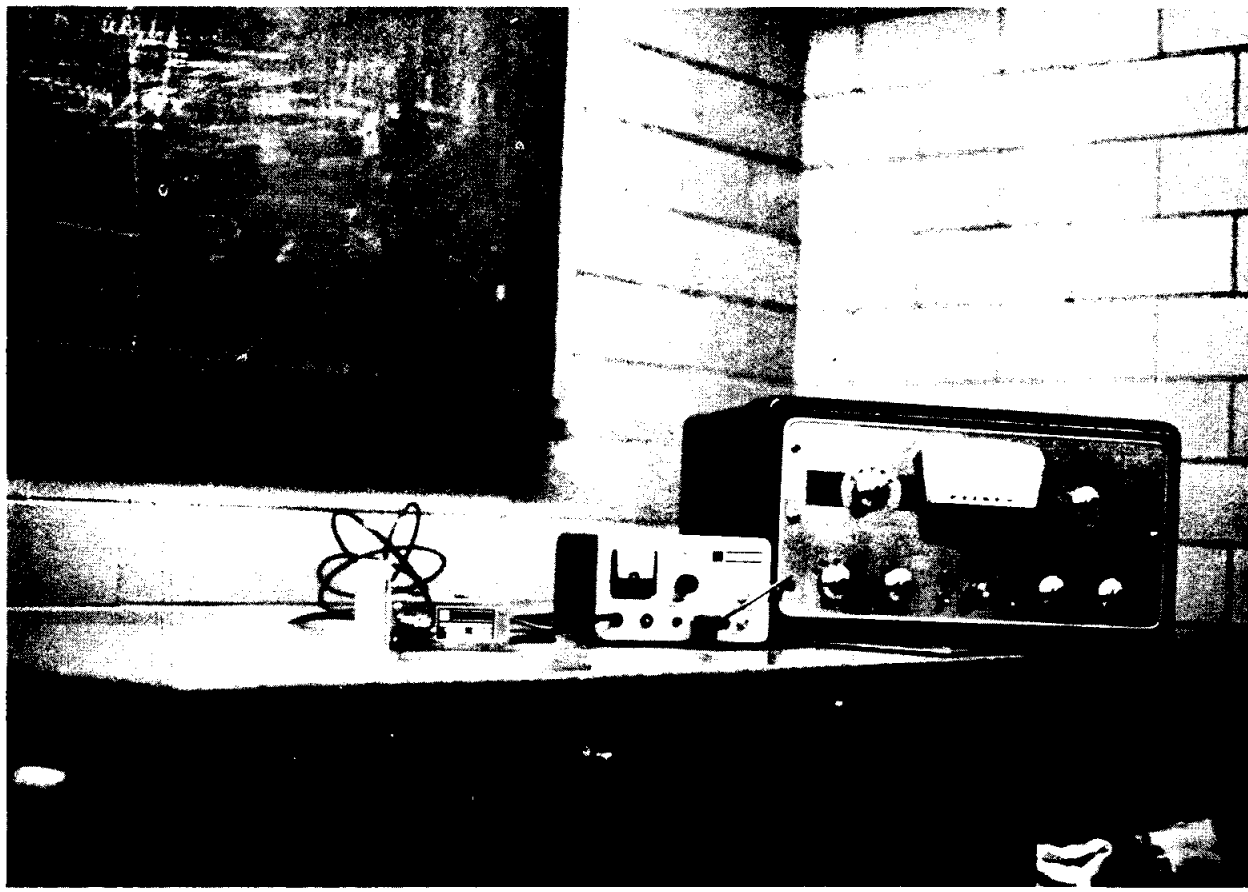


Figure 3 — Overall View of Instrumentation

Figure 4 — X-ray Phantom with Radiation Probe Attached

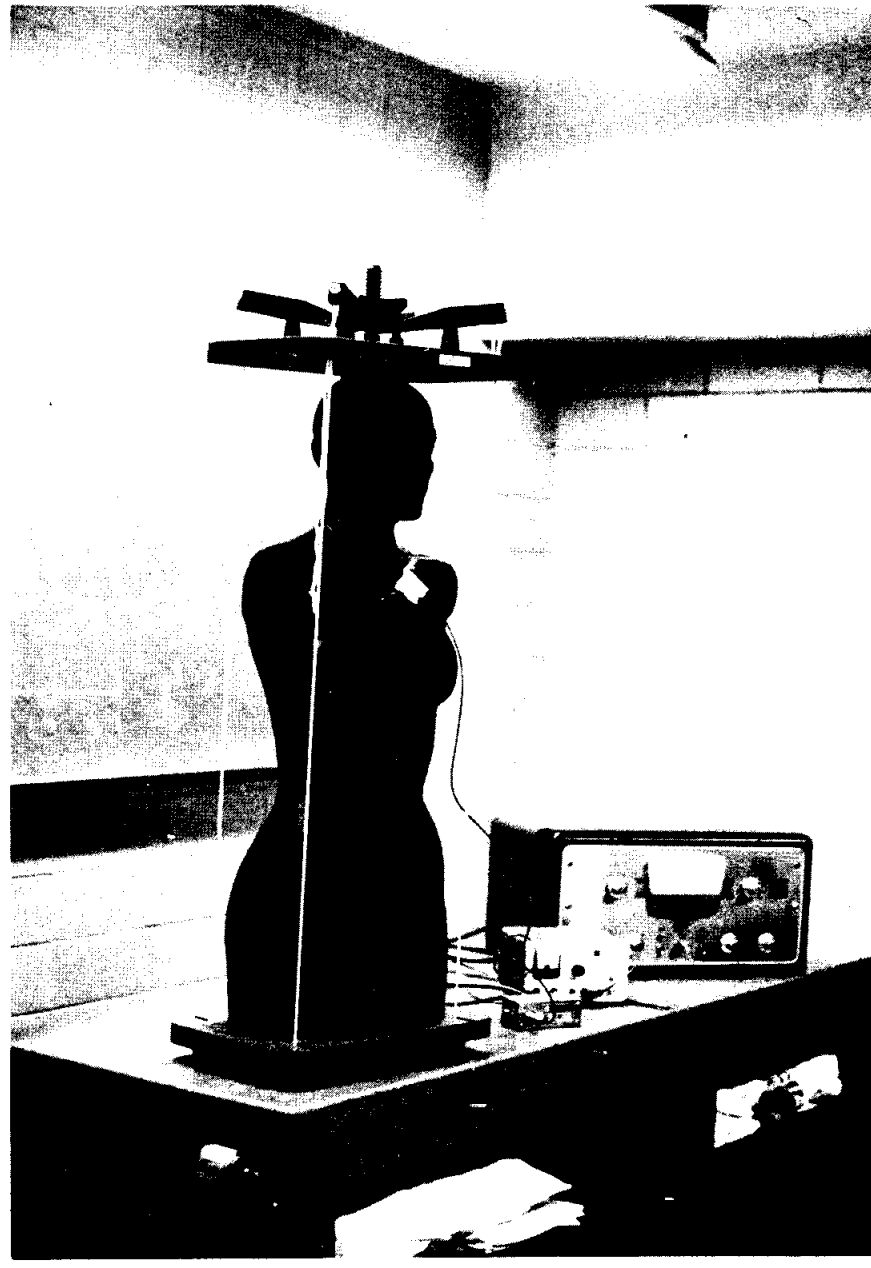


Figure 5 — Overall View of X-ray Phantom and Instrumentation

The second involves treatment of patients who have normal lungs but who through some circumstance (for example, use of drugs) have temporarily lost the ability to breathe; i.e., the control mechanisms which regulate respiration are temporarily inactive.

It is generally felt that the treatment of such people could be done more efficiently and without the danger of hyperventilation if a means of sensing the components of the expired gases could be implemented in such a fashion as to control the operation of the respirator to achieve proper respiration of the individual. Hyperventilation of the lungs is not only undesirable, it can be positively harmful. Essentially, the system would be required to sense the oxygen and carbon dioxide partial pressures in the inspired gas and the expired gas. Inspired gas has a carbon dioxide content of nominally zero, with an oxygen partial pressure of approximately 150 mm. The expired gas, on the other hand, has a carbon dioxide content of from 42 to 58 mm, and an oxygen content of approximately 100 mm. Five percent accuracy in sensing these compositions would be acceptable.

In addition to a means of sensing the components of the inspired and expired gases, it is also desired to incorporate an integral electronic control system which would program the operation of the respirator to achieve optimum respiration of the patient based upon the data provided by the $CO_2$ and $O_2$ sensors.

Status:

During this quarter, follow-up on the suggestion from Mr. John Samos, Technology Utilization Officer at Langley Research Center, on the use of fluidic devices to measure the components of atmospheric gas was continued. Since the source of this technology was the Harry Diamond Ordnance Laboratories, it was necessary to establish a "need-to-know" before discussions could be held with the researchers at Harry Diamond Laboratories. During the quarter the "need-to-know"

was established. A conference with members of the Biomedical Section of the Harry Diamond Laboratories was held. Specific details of the biomedical problem were outlined, and the possibility of using fluidic techniques in this particular application were extensively discussed. The net result of these discussions was that the techniques suggested by Mr. Samos could not be implemented without a costly engineering investigation. Even then, the probability of success in employing these techniques could not be considered certain. Such a development program would involve the expenditure of considerable amounts of effort and funds. The researcher has limited funding so that he cannot support such a development program even if the success of such a development program were assured. As a result, within the present constraints under which the problem is defined, it does not appear that the application of fluidics techniques to this problem can be accomplished.

WF-36

## Implantable Pressure Sensor and Telemetry Unit for Measurement of Fluid Pressure in the Cranial Cavity

Dr. D. L. Kelly, Jr.
Bowman Gray School of Medicine

Description of Problem:

This problem is related to Biomedical Problem WF-37,"An Implantable Valve Which Can be Remotely Opened and Closed from Outside the Body." Both of these problems were identified as a result of discussions with Dr. Kelly of the Department of Neurosurgery at Bowman Gray School of Medicine. Dr. Kelly is engaged in research activities associated with the build-up of fluid pressure in the cranial cavity. Many people have a fluid build-up, called hydrocephalus, that occurs in the cranial cavity, and this pressure must be relieved. This is usually accomplished by inserting a pick-up tube inside the cranial cavity and running a piece of tubing down underneath the skin in the rear of the head, finally

discharging the fluid into one of the blood vessels where the fluid is dispersed. A special one-way valve known as a Holter valve is used to prevent passage of blood into the cranial cavity.

Dr. Kelly is interested in monitoring the pressure build-up in people with hydrocephalus. Using a pressure transducer and telemetry system which can be implanted, along with a special one-way valve that can be remotely opened and closed from outside the body, the cranial cavity can be closed off. Pressure build-up can then be monitored as a function of time on a given individual. This data is the information which is of interest to Dr. Kelly; i.e., the rate of pressure build-up in the cranial cavity of people afflicted with hydrocephalus.

Status:

There are numerous sources of technology which can be identified as directly applicable to this problem. Indeed, much of the work on biotelemetry equipment at Ames Research Center could be applied to this problem if access to this technology could be arranged. One promising approach to the solution of this problem has resulted from the interaction of the Biomedical Application Team with researchers at the University of North Carolina Medical School. Contact was made with Mr. Stan Hutcheson who is an electrical engineer in the Parapsychology Lab at the University of North Carolina Medical School. Mr. Hutcheson has been designing, for medical use, a number of biotelemetry units for pressure, temperature, and pH measurements. Discussion with Mr. Hutcheson revealed that, in addition to his work at the University of North Carolina Medical School, he is also a member of Microtronics Corporation, Carrboro, North Carolina which fabricates custom biomedical instrumentation. Initial discussions with Mr. Hutcheson has indicated that their firm has the capability to construct the required biotelemetry equipment for this particular application. Preparations are being made for presenting a cost estimate to the researcher. Since costs will determine whether or not the technology can be used in this application, it would be necessary to obtain such information before the feasibility of using these techniques can be established.

WF-37

## An Implantable Valve Which Can be Remotely Opened and Closed from Outside the Body

Dr. D. L. Kelly, Jr., Bowman Gray School of Medicine

Description of Problem:

This problem is related to biomedical problem WF-36, "Implantable Pressure Sensor and Telemetry Unit for Measurement of Fluid Pressure in the Cranial Cavity." Both of these problems were identified as a result of discussions with Dr. Kelly of the Department of Neurosurgery at Bowman Gray School of Medicine. Dr. Kelly is engaged in research activities associated with the buildup of fluid pressure in the cranial cavity. Many people have a fluid build-up, called hydrocephalus, that occurs in the cranial cavity, and this pressure must be relieved. This is usually accomplished by inserting a pickup tube inside the cranial cavity and running a piece of tubing down underneath the skin in the rear of the head, finally discharging the fluid into one of the blood vessels where the fluid is dispersed.

A special one-way valve known as a Holter valve is used to prevent passage of blood into the cranial cavity. Not infrequently, this valve will stick closed, and pressure will begin to buildup in the cranial cavity of the individual. In addition to this particular difficulty, the present valve does not permit any control over flow; i.e., it is a one-way valve which is always open in the forward direction and always closed in the reverse direction.

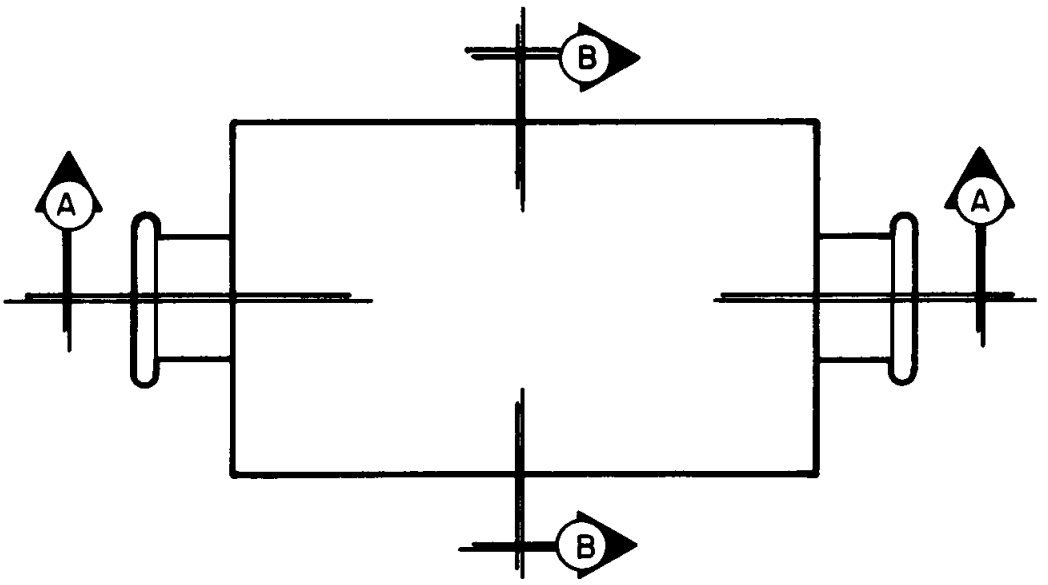
It is desirable on certain occasions to be able to close off the valve and to observe the rate of pressure buildup. Then, at some selected pressure level, the valve would be opened, permitting the fluid to drain out of the cranial cavity. Since the drain tube and valve are permanently implanted (unless it becomes necessary to remove the valve because it becomes clogged), operation of the valve must be accomplished from outside the body without external wires or connections.

Status:

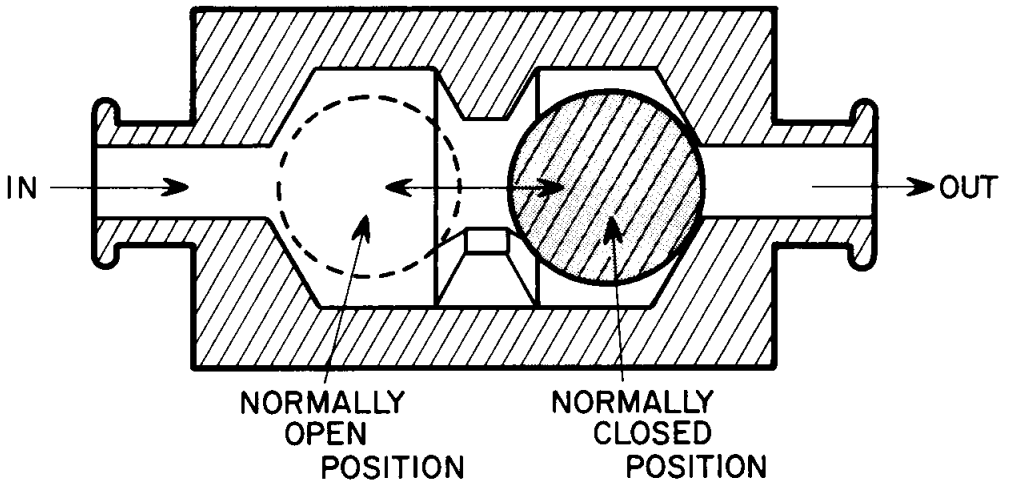
A potential solution to this problem was identified during the last quarter. The potential solution in this case is a modification of the valve used in the prosthetic urethral valve, Biomedical Problem WF-3. The potential solution which has been formulated is basically a restrained ball type check valve with a mechanical override to permit opening the valve. (See Figure 6.) The entire valve body, seat, and ball restraints are molded from silicone rubber. A rigid ball is employed as the moveable element.

The ball is restrained in its seat by a small static pressure which keeps the valve closed under normal circumstances. The body of the valve and the valve seat itself are fashioned from a flexible silicone rubber compound. The valve is normally closed, but can be opened by the application of force with the fingers in a pinching motion on the valve body. This deforms the valve seat permitting fluid to flow around the ball of the valve and to escape. Deformation of the valve seat can be accomplished through a layer of skin and tissue so that implantation subcutaneously can still permit manual operation of the valve.

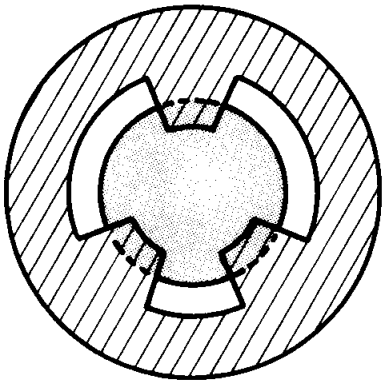
It is presently thought that this valve can be modified to permit the valve to be placed in either a normally closed or a normally open position by squeezing on the body of the valve. The basic proposed valve configuration has been carefully detailed, and evaluation of the proposed solution is currently underway by the Biomedical Application Team and the researcher. It appears that the major difficulty in implementing this proposed solution to the problem will lie in obtaining a source to fabricate these valves in very small sizes.




TOP VIEW




SECTION A-A



SECTION B-B

Figure 6 – Proposed Value Configuration

WF-41

## Low Cost, Swallowable, Temperature-Sensing Telemetry Capsule

Dr. R. M. Kerr, Bowman Gray School of Medicine

Description of Problem:

Dr. Kerr is interested in monitoring temperature in various portions of the gastrointestinal tract. A low-cost unit applicable to clinical medicine is desired. A swallowable device with no wires or other attachments is considered to be mandatory, requiring the use of a biotelemetry temperature sensing system.

Status:

As reported in the last quarterly report, a commercially available unit from the Telefunken Corporation of West Germany markets units known as Heidelberg capsules that may be applicable to this problem. The United States distributor for this unit, Medintron Corporation of America, has been contacted for performance characteristics, size, and cost information. In addition, during this quarter, Mr. Stan Hutcheson at the University of North Carolina Medical School was contacted as a result of the Biomedical Application Team activities. Mr. Hutcheson is an electrical engineer in the Parapsychology Lab at the University of North Carolina Medical School. Mr. Hutcheson has been designing, for medical use, a number of biotelemetry units for pressure, temperature, and pH measurements. Discussion with Mr. Hutcheson revealed that, in addition to his work at the University of North Carolina Medical School, he is also a member of Microtronics Corporation, Carrboro, North Carolina which fabricates custom biomedical instrumentation. Initial discussions with Mr. Hutcheson has indicated that their firm has the capability to construct the required biotelemetry equipment for this particular application. Preparations are being made for presenting a

cost estimate to the researcher. Since costs will determine whether or not the technology can be used in this application, it would be necessary to obtain such information before the feasibility of using these techniques can be established.

WF-53

Means of Obtaining the Velocity Spectrum of Blood Flowing in Arteries and Veins

Dr. G. S. Malindzak, Jr., Bowman Gray School of Medicine

Description of Problem:

Blood flow in blood vessels is generally considered to be laminar; thus, the blood flow velocity is at a maximum in the center of the blood vessel and essentially zero on the edges. The result is that, if one were to consider a cross section of such a model, the maximum velocity would exist in the center of the vessel, and concentric rings indicating equal velocity contours would radiate out to the walls of the vessel where the velocity is essentially zero. The average flow velocity is obtained through a number of different types of measurements; however, it is felt that information on the entire velocity spectrum of the blood flowing in veins and arteries would be of great value. Doppler flowmeters offer the possibility of obtaining the velocity spectrum and the shape of the velocity distribution curve. Present commercially available Doppler flowmeters indicate average velocity. It is desired to determine if the required information can be obtained by modification of existing Doppler flowmeters or other simple means.

Status:

Problem specification has been completed, and initial searching procedures have been instituted. A news release was noted by one of the members of the RTI Biomedical Application Team which indicated that the

Southwest Research Institute had several contracts in the area of ultrasonic instrumentation. As a result, a request was made to the Southwest Research Institute for information applicable to this particular problem. A final report on an SwRI-developed blood pressure measuring system was received; however, the material was not particularly applicable to this problem. We were informed that they are working on a second contract for Brooks Air Force Base to develop small, catheter tip, blood flow velocity transducers. It was indicated that some of this work may be applicable to the problem; however, the people at SRI were not at liberty to discuss details of this work at the present time. Other information sources are being used, and a full retrospective search of the aerospace literature was performed by the North Carolina Science and Technology Research Center on ultrasonic Doppler spectrum analysis. This search has just been received and will be evaluated during the next quarter.

WF-54

## An Improved Sensing System for Indicator-Dilution Studies

Dr. H. D. Green and Dr. C. E. Rapela,
Bowman Gray School of Medicine

Description of Problem:

Indicator-dilution techniques have proved very useful in obtaining: (1) blood volume within a segment of the vascular system, (2) mean blood flow through a segment of the vascular system, and (3) particulate velocity. Fundamentally, the technique consists of adding a known concentration of an indicator (dye or radioactive) to a volume of fluid. Then, when the indicator is thoroughly mixed with the volume of fluid, a measurement of the concentration of the indicator permits calculation of the volume of fluid. First employed in a static system, the technique

has been extrapolated to dynamic systems. Researchers at Bowman Gray School of Medicine have been engaged in an experimental program to define accurately the methods which can be used to obtain reliable data from these types of measurements.

Initial studies have been made using a simplified model of a vascular segment; i.e., a cylindrical tube. In this experimental model an indocyanine dye, sensitive in the infrared spectrum, is injected into a moving stream of liquid which is being pumped through a polyethylene tube of uniform diameter. Dye is injected into the flowing liquid stream by a hypodermic syringe driven by a constant speed linear actuator. The total length of time that the dye is being injected into the stream can be varied from 0.1 second to 10 seconds to control the total amount of dye injected. Flow velocity of the fluid in the tube is approximately 20 $cm^3$/second.

Within the tube, flow is usually considered to be laminar, which (when viewed in cross section perpendicular to the tube axis) corresponds to a series of concentric iso-velocity rings of fluid with the highest velocity nearest the axis of the tube and the lowest velocity nearest the wall of the tube. Because of this characteristic, dye injected near the center of the tube propagates through the system much more rapidly than dye injected near the wall, making the point of dye injection very critical. To overcome this problem, a rotary, mechanically-operated mixer is installed immediately upstream from the injection site. This mixer induces turbulence, breaking up the laminar flow pattern so that, in the region of the injection site, the fluid flow is turbulent, producing a velocity profile which is approximately uniform across the entire diameter of the tube just below the mixer.

Windows on opposite sides of the polyethylene tube have been used to observe the indicator dye concentration in the flowing stream. A source of radiant energy is used to illuminate one of the windows, and a photocell sensitive in the absorption spectrum of the indicator dye is placed on the opposite side of the tube in the other window. From

the photocell reading, the concentration of indicator in the liquid flowing past the photocell can be determined. This dye concentration is an average of the concentration across the entire diameter of the tube.

It is desired to examine small portions of the volume of the tube so as to determine the regional characteristics of the dye distribution within the tube. In order to permit such a determination to be made, the researchers desired to obtain an indicator absorption apparatus which could examine these small volumes of fluid within the tube. They felt that an approach using fiber optics offered the best possibility of yielding meaningful measurements at a reasonably low cost. The Biomedical Application Team was asked to consider the feasibility of performing such measurements using fiber optic illuminators and pick-up devices. In addition, it was desired to examine any other techniques capable of performing this measurement which could be identified. It was also desired to obtain a device which could be used not only in the transmission mode but in a backscatter mode if such proved feasible.

Status:

This problem was documented as a transfer and discussed in the first quarterly report[1]. During this quarter, the Research Triangle Institute has fabricated an improved indicator dilution sensing system for the Bowman Gray School of Medicine. The unit has been demonstrated to the researchers, and preliminary tests were conducted in order to obtain the final design characteristics necessary to permit

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[1] Biomedical Applications of NASA Science and Technology, Quarterly Progress Report 1, 15 June 1968 to 14 September 1968

optimum useage of the equipment. These adjustments are currently being made using whole blood as a test liquid, which is the liquid that will be used by the researcher. When the final adjustments have been made, the unit will be employed in a full-scale test procedure to be conducted by the researchers at the Bowman Gray School of Medicine. This final testing period will permit optimization of the performance of the equipment. Then, the unit will be used in the actual experimental program of the researchers.

WF-55

## A Simple Means of Sensing Whether a Respirator is Actually Performing the Respiratory Function on Humans

Dr. R. A. Kemp,
Bowman Gray School of Medicine

Description of Problem:

Dr. Kemp is interested in a very simple and reliable means of sensing whether a respirator is actually performing the respiratory function on the patient or whether, through some malfunction, the patient is not being respired by the respirator. The type of respirator in use by the researcher is designed so that it pumps into the respiratory passages of the patient until a fixed pressure is obtained. When the fixed pressure is reached, the ventilation phase is ended, and the expiration phase of the cycle begins. If, because of some obstruction or because of a kink in the respirator hose, the patient is cut off from the respirator, the machine is unable to sense this condition. It merely pumps up against the pressure in the hose until the desired pressure is reached and then cuts off and begins the remaining part of the cycle.

As a result, it is possible for the respirator to be operating perfectly, from a mechanical standpoint, and the patient can be deprived

entirely of his air supply and thus die. Nose clip type sensors have been employed, but they are not very satisfactory because they are very difficult to maintain in place and are bulky. In addition, quite frequently the airway resistance through the nasal passages is such that it is desirable for the respirator input to be shunted so as to enter through the throat.

Status:

As reported in the last quarterly report, information on the design of a unit constructed at the NASA Ames Research Center was received from Mr. George Edwards. An analysis of the specifications for the unit which had already been completely designed by the Ames Research Center revealed that some of the components required in the system were not easily available at the present time. The documents received from Ames were preliminary documents. During this quarter, final documentation of the backup package was completed by NASA Ames Research Center,and Mr. Edwards forwarded to us the latest information on the respiration sensor and alarm system. The latest information appears to use components which will not be difficult to obtain. At the present time the unit is being evaluated by the researcher, and cost estimates for construction of such a device are being evolved.

WF-56

An Improved Fluid Pressure Calibration System

Dr. G. S. Malindzak, Jr., Bowman Gray School of Medicine

Description of Problem:

The Department of Physiology of the Bowman Gray School of Medicine, Wake Forest University, maintains a fluid pressure calibration system which is used as a standard for calibrating arterial pressure transducers

used by medical researchers in that department. The system consists of an electromechanical transducer and a fluid-filled pressure chamber with provision for connecting external pressure measuring transducers into the pressure chamber.

The electromechanical transducer currently employed is a commercially available underwater loudspeaker which is energized by a low frequency sine wave function generator. The response characteristic of the underwater speaker in the present system is very poor and not accurately known at the low frequencies ( < 10 Hz.)

It is desired to generate pressures within the pressure chamber that have constant amplitude and phase characteristics with frequency. Two different approaches suggest themselves as means of solving this problem. First, the ideal solution would be to obtain a pressure generator which can produce constant pressure sinusoidal pulsations over a frequency range from near 1/10 hertz to 150 hertz. A second approach is to use the present underwater speaker and modify the driver-amplifier system which actuates it. This requires that the frequency response characteristics of the speaker be accurately determined throughout the frequency range of interest. Next, it requires the design of an amplifier whose frequency amplification characteristic is such that the combination of amplifier and transducer produces a constant amplitude pressure wave over the frequency range of interest.

Status:

As discussed in the previous quarterly report, the Engineering and Environmental Sciences Division of the Research Triangle Institute has agreed to conduct a series of tests to determine the frequency response characteristics of the transducer presently used. The test procedures were formulated, and initial testing was begun during this quarter. Unfortunately, during the initial testing procedures the transducer used by the researcher failed. As a result, it was necessary to return the transducer to the manufacturer for repairs. During most of this quarter the transducer remained at the manufacturer's plant for repairs. It has,

however, been very recently returned. Tests to determine the response of the transducer will be resumed during the following quarter. When the tests have been completed, an evaluation will be made as to the feasibility of designing an amplifier driver system to accomplish the desired purpose. If the feasibility is established, the Engineering and Environmental Sciences Division of the Research Triangle Institute will provide a quotation to the researcher on the cost of designing and fabricating such a unit.

In addition to the efforts of the Engineering and Environmental Sciences Division to determine the frequency response characteristics of the pressure transducer presently used by the researcher, a full retrospective search of the NASA literature has been conducted. This search was designed to reveal the existence of pressure calibration systems which have already been designed or which are in use in the aerospace program that may be applicable to this problem. The search is presently being evaluated.

WF-61

An Improved Method of Determining Volume Elasticity of Blood Vessels

Dr. G. S. Malindzak, Jr., Bowman Gray School of Medicine

Description of Problem:

The volume elasticity of blood vessels is an important parameter in the evaluation of total cardiovascular function. Knowledge of this parameter is necessary in formulating a meaningful model of the behavior of the cardiovascular system under a variety of states in health and disease. In addition, when blood vessels lose their elasticity, it imposes a greater load on the heart, resulting in a reduction of efficiency in cardiovascular performance. Present methods of determining the volume elasticity are at best approximations to the "real" value. In addition, the blood vessels to be tested must be removed from the body cavity. Present methods of determining this parameter include securing

a small section of the vessel in a device so that the vessel can be subjected to pressure changes from within. The volume elasticity is computed from the rate at which the pressure changes in response to a change in vascular volume. A simple and precise method of measuring volume elasticity is desired. Although not essential (at this time) for this particular problem, it would nevertheless be extremely useful if such measurements could be made without removing the blood vessel from its intact position within the tissue.

Status:

Further consultation with the researcher has been held during this quarter to insure that the problem has been accurately defined. Preliminary information searching procedures have been instituted, and efforts have been made to perform a full retrospective search of the aerospace literature in this particular problem area. Some difficulty is being experienced in formulating a search strategy which will yield meaningful output from the information system. Hopefully, some combination of search terms will be devised during this quarter which will permit a retrospective search in this area.

## 5.0 Problem Review

During this quarter, a number of problems have been reviewed to determine whether further action was needed by the Biomedical Application Team. As a result, 13 problems have been classified as inactive.

There are various reasons for which problems are classified as being inactive. These reasons are:

(a) Successful transfer.

(b) Satisfactory solution has been identified but transfer cannot be completed for economy or other reasons.

(c) Researcher has no further interest in the problem.

(d) Problem as originally stated was too broad or general.

(e) Researcher has found his own solution.

(f) Problem is too difficult; i.e., the problem as given to the Biomedical Application Team is presently the focus of large expenditures of money, research, and developmental effort so that the likelihood of success by the Biomedical Application Team is considered to be sufficiently low as to assign an extremely small probability to solution of the problem.

(g) As a result of personnel transfer in the medical institutions, the problem has either been closed or transferred to another institution along with the investigator and given a new number.

(h) Problem has been redefined and given a new number.

(i) Information obtained as a result of searching activities has provided no further insight into the problem.

The problems which were classified inactive are listed below. The letter designation following the problem title indicates the reason for such classification.

| | |
|---|---|
| AEI-2 | A Cathode Ray Tube Camera for Ultrasonic Scanning Systems (c) |
| DU-30 | Technique for Heparinizing Catheters (c) |
| DU-33 | Fabrication Source for Special Purpose Catheter to be Used in Left Heart Bypass (c) |
| DU-34 | Electronic Control and Synchronization System for Left Heart Bypass Pump (c) |

| | |
|---|---|
| HSS-1 | A Method of Measuring and Telemetering the Force Applied to Broken Bone Joints by Implanted Braces (c) |
| HSS-2 | A Method for Measuring and Telemetering Pressures on the Surface of Prosthetic Hip Joints (c) |
| MFH-2 | Catheter Mounted Flow and Pressure Transducers (c) |
| NCSU-1 | The Application of Mathematical Modeling Techniques to the Cardiovascular System (i) |
| RU-1 | A Survey of Computer Techniques for Analyzing Physiological Data (c) |
| RU-2 | A Survey of Recently Developed Transducers for Monitoring Physiological Parameters (c) |
| UNCD-11 | A Means of Sampling Bacteria in the Nasal and Sinus Cavities Which is Simpler and Less Unpleasant to Patients (c) |
| VA-1 | Improved Techniques for Measuring Blood Flow Continuously (c) |
| VA-3 | Transducers Which Can Measure Blood Pressure and Are External to the Body (c) |

## 6.0 Information Searching

### 6.1 Computer Searches

During this quarter, a total of five new retrospective information searches were made of the NASA Aerospace Literature. The searches were performed for the Biomedical Application Team by the North Carolina Science and Technology Research Center. Information obtained from these searches has been used to support the searching activities associated with the medical problems which have been active during the quarter. Computer Evaluation Reports on each search are given in Appendix A. Retrospective computer information searches made during this quarter are listed below:

| Subject | Search No. |
|---|---|
| Physiological Cooling Probe | 1370 |
| Dynamic Response of Pressure Transducers | 1397 |
| Tooth Mobility Testing | 1409 |
| Ultrasonic Doppler Spectrum Analysis | 1502 |
| Aversion Therapy | 1503 |

In addition to these retrospective searches, one Current Awareness Search has been maintained by the Biomedical Application Team during this quarter.

| Subject | Search No. |
|---|---|
| Oxygen Tension in Tissue and Biotelemetry | 1469 |

In addition to formalized computer searching of the aerospace literature, we have extensively used another searching method to obtain information from the NASA information banks. Namely, we have on numerous occasions requested a manual search on very specific topics in the aerospace literature. These manual searches are performed in somewhat the following manner. If the subject of the problem is considered to be extremely specific, then the NASA index and thesaurus are consulted using specific indexing terms to determine the number of documents in that subject area that are available in the NASA information system. If the number of

documents is small; i.e., generally in the order of 10 or less, then it is more feasible to merely pull all the documents under that index term and evaluate either them or their abstracts without resorting to a computer search. This is not only less expensive, but it is also much quicker. This procedure has been an extremely effective and a very useful adjunct to our normal computer searching procedures. These types of manual searches have been undertaken on some 30 percent of the active problems during this quarter.

### 6.2 Other Searching Methods

In addition to these more or less formalized methods for obtaining information which relates to the solution of biomedical problems, the Biomedical Application Team has utilized three other information sources in seeking answers to biomedical problems. First, in every case the combined experience of the Biomedical Application Team members has been applied to the problems to ascertain if there exists within their knowledge and experience practical solutions to each problem. Indeed, this particular method of searching using the experience of technically trained personnel has not been limited only to members of the Biomedical Application Team. In fact, many specialists in the various disciplines of engineering and research have been routinely consulted to obtain information and advice on specific problems as deemed appropriate.

Another source of information relating to Biomedical Problems is the open literature. The Biomedical Application Team scans many of the related technical journals and biomedical engineering journals on a routine basis in order to maintain an awareness of techniques and equipment which are being developed. Access to the medical literature is maintained by use of Index Medicus which is available to all members of the Biomedical Application Team.

Finally, in all biomedical problems which involve measurement, instrumentation, or hardware, the commercial literature is surveyed to insure that items have not already been developed which will fulfill the researcher's need. If commercial items are identified which can

fulfill the researcher's need, he is, of course, apprised of the availability of such equipment. Keeping abreast of the product output of all the manufacturers of biomedical instrumentation is, however, a formidable task. To permit a reasonable degree of thoroughness in surveying the available instrumentation and hardware for use in the biomedical field, a file of available equipment from biomedical manufacturers is maintained by the Biomedical Application Team. To aid in this process of keeping abreast of commercial suppliers, the services of NCSTRC are used to search the Sweet's Industrial Information System which is an indexed, rapid-access, microfilmed catalog of the products of 5,670 equipment suppliers in the United States.

## 7.0 Other Activities and Projections for the Third Quarter

The Midwest Research Institute's Biomedical Application Team is assisting D. W. Douglas of Missouri University (MRI Problem No. MU-19) on electrocardiograph measurements. Mr. Douglas wants to know if EKG information is lost during multiplexing. RTI has worked with Dr. J. P. Boineau of Duke University Medical Center on multichannel EKG measurements, and it was felt that Dr. Boineau might be able to offer some valuable comments. Accordingly, RTI contacted Mr. Douglas and suggested that he talk with Dr. Boineau.

In another area, the normal activities of the Biomedical Application Team resulted in bringing together several researchers of different disciplines who have subsequently written a proposal to NIH. Dr. Susan Dees of Duke University Medical Center, Dr. Lyman Ripperton of RTI, and Harry Hamilton of RTI have proposed to study the effect of climatic conditions on attacks of allergy in children.

The Southwest Research Institute is working with Dr. A. E. Rodin of the University of Texas (SwRI Problem No. GLM-16) on "Tumor Mass Determination on Rat Leg". A computer search had disclosed few results. The RTI Biomedical Application Team discussed the problem with Dr. F. L. Thurston of Duke University. This discussion disclosed a paper on the use of ultrasonic holography for measuring soft tissue tumors in rats. This information was given to Dr. Ray W. Ware of Southwest Research Institute.

Dr. J. N. Brown and Dr. F. T. Wooten attended the sessions on biomedical engineering at the Symposium of North Carolina Sections of IEEE held at Greensboro, N. C., on November 6-7. Dr. J. N. Brown was General Chairman of the Symposium.

During this quarter, a number of factors have been operating within the medical schools which have made demands on the time of the researchers. This has meant that less opportunities have been available to contact researchers than in the previous quarter. These factors are: (1) During November there was a deadline on grant proposals for NIH, so that most researchers occupied a major portion of their extra time in grant preparation, (2) Midterm examinations also occurred in November so that those researchers with teaching responsibility were even more pressed for time, and (3) The

Christmas holiday period of approximately 2 weeks in the medical schools also reduced the total time available for team consultation. All of these factors operating together have made it difficult to obtain appointments with researchers during this quarter, either to discuss new problems or to evaluate information obtained on old problems.

As a result, the numbers of new problems identified along with the number of transfers and potential transfers were relatively low during this quarter. Most of our activities have thus been directed toward obtaining information related to problems already identified. Much of this information is potentially useful and will be presented to the appropriate researchers as they are available during the next quarter.

During the past quarter, several small manufacturers of biomedical equipment in this area have expressed an interest in the Biomedical Application Team and the NASA Technology Utilization Programs. Plans have been made to meet with representatives of these companies during the next quarter to discuss ways in which the Biomedical Application Team can interact with these companies to our mutual benefit.

## 8.0 Financial Summary

A summary of contract expenditures for the period 15 September 1968 through 14 December 1968 is presented in the table below:

| Item | Expenditure |
|---|---|
| Materials | $ 125.93 |
| Services | 255.57 |
| Travel | 837.02 |
| Consultants | 880.00 |
| Labor | 17,635.12 |
| Overhead | 16,929.72 |
| Fee | 2,204.16 |
| Total Quarterly Costs | $38,867.52 |

# APPENDIX A

# COMPUTER EVALUATION REPORTS

COMPUTER EVALUATION REPORT

Title Search & RDC Number: Physiological Cooling Probe #1370

Problem Name & Number: Localized Cooling of Heart Muscle DU-37

Date Search Initiated: October 4, 1968

Descriptors:

| | |
|---|---|
| Cooling | Method |
| Tip | Spot |
| Probe | Cooling |
| Element | Cooling System |
| Physiology | Gas Cooling System |
| Technique | Refrigeration |

Date Search Received: October 7, 1968

Number of Hits: 49

Date Documents Requested by Researcher: 11/68

Number of Documents Requested & Document Numbers:

A63-16763
A65-14457
N66-27883
A66-16405
N63-10946

Team Evaluation of Search:

Researcher Evaluation of Search:

Plans for Use of Information:

COMPUTER EVALUATION REPORT

Title Search & RDC Number: Dynamic Response of Pressure Transducers #1397

Problem Name & Number: An Improved Fluid Pressure Calibration System WF-56

Date Search Initiated: October 21, 1968

Descriptors:

| | |
|---|---|
| Hydrophone | Frequency Response |
| Microphone | Dynamic Response |
| Pressure Transducer | Transient Response |
| Transducer | Transfer Function |
| Sound Measurement | Calibration |
| Electroacoustics | |
| Fluid | |
| Liquid | |

Date Search Received: October 25, 1968

Number of Hits: 50

Date Documents Requested by Researcher:

Number of Documents Requested & Document Numbers:

Team Evaluation of Search:

Researcher Evaluation of Search:

Plans for Use of Information:

COMPUTER EVALUATION REPORT

Title Search & RDC Number: Tooth Mobility Testing #1409

Problem Name & Number: A Device to Measure Looseness of Teeth UNCD-15 and Method of Determining if Tooth Roots are Attached to the Jaw Bone Structure UNCD-18

Date Search Initiated: October 24, 1968

Descriptors:

| | |
|---|---|
| Tooth | Bond |
| Mobility | Cavity |
| Movement | Crack |
| Interfacial Strain | Stability Test |
| Interface Stability | Impact Tests |
| Discontinuity | Ultrasonic Testing |
| Interface | Vibration Testing |
| Void | Nondestructive Testing |
| Flaw | |

Date Search Received: October 30, 1968

Number of Hits: 97

Date Documents Requested by Researcher:

Number of Documents Requested & Document Numbers:

Team Evaluation of Search:

Researcher Evaluation of Search:

Plans for Use of Information:

COMPUTER EVALUATION REPORT

Title Search & RDC Number: **Oxygen Tension in Tissue and Biotelemetry #1469**

Problem Name & Number: **Oxygen Content of Ichthyological Ovarian Fluid NCSU-5**

Date Search Initiated: **November 18, 1968**

Descriptors:

**Biotelemetry**
**Oxygen Tension**
**Bioengineering**

Date Search Received: **November 22, 1968**

Number of Hits: 136

Date Documents Requested by Researcher:

Number of Documents Requested & Document Numbers:

Team Evaluation of Search:

Researcher Evaluation of Search:

Plans for Use of Information:

COMPUTER EVALUATION REPORT

Title Search & RDC Number: Ultrasonic Doppler Spectrum Analysis #1502

Problem Name & Number: Means of Obtaining the Velocity Spectrum of Blood Flowing in Arteries and Veins WF-53

Date Search Initiated: December 11, 1968

Descriptors:

- Frequency Shift
- Doppler Effect
- Coherent Acoustic Radiation
- Ultrasonic Wave Transducers
- Ultrasonic Radiation
- Ultrasonic Tests
- Ultrasonics
- Frequency Scanning
- Frequency Analyzers
- Spectra
- Spectral Resolution
- Spectral Energy Distribution
- Signal Analysis
- Frequency Distribution
- Spectrum Analysis

Date Search Received: December 11, 1968

Number of Hits: 39

Date Documents Requested by Researcher:

Number of Documents Requested & Document Numbers:

Team Evaluation of Search:

Researcher Evaluation of Search:

Plans for Use of Information:

COMPUTER EVALUATION REPORT

Title Search & RDC Number: Aversion Therapy #1503

Problem Name & Number: A Miniaturized Electrical System to Shock the Tongue of Patients When It is Pressed Against the Rear of Their Teeth UNCD-25

Date Search Initiated: December 11, 1968

Descriptors:

| | |
|---|---|
| Penalties | Human Performance |
| Reward (Psychology) | Entrapment |
| Deconditioning | Confusion |
| Pain | Escape (Abandonment) |
| Avoidance | Arousal |
| Habituation (Learning) | Electric Stimuli |
| Inhibition (Psychology) | Psychology |
| Conditioning (Learning) | Animal Study |
| Human Behavior | Human Factor |
| Human Reactions | Conditioned Response |

Date Search Received: December 11, 1968

Number of Hits: 52

Date Documents Requested by Researcher:

Number of Documents Requested & Document Numbers:

Team Evaluation of Search:

Researcher Evaluation of Search:

Plans for Use of Information:

# APPENDIX B

# TRANSFER CRITERIA

## Appendix B

## Transfer Criteria

As a result of the combined experience of the Biomedical Application Teams at the Research Triangle Institute, Midwest Research Institute, and Southwest Research Institute, it has been observed that information supplied to biological and medical investigators can be used in a variety of immediately useful or potentially useful ways. In order that there will exist a uniform procedure for designating successful technology transfers, the following criteria for successful or completed transfers have been established:

(a) Results in a new biomedical product, technique, or professional conclusion.

(b) Accelerates the application of the state of the art in biomedical or medical research procedure.

(c) Exposes technology which the investigator has re-engineered for his purposes.

(d) Is used by an investigator to develop a proposal.

(e) Allows the investigator to complete his research project which might otherwise have been delayed or not finished.

(f) Causes the investigator to redirect his effort to phase with other research which came to his attention as a result of the work of the Team.

(g) Conserves an investigator's resources by avoiding duplicatory research.

(h) Causes the investigator to cancel or defer his project because it may be premature or costs that are forecasted are too high.

# APPENDIX C

# CONTRIBUTION EVALUATION REPORTS

## CONTRIBUTION EVALUATION FORM

**Organization:** NASA Langley Research Center

**Contributor:** Mr. John Samos

**Biomedical Problem Abstract:** WF-31 A Servo-Controlled System to Measure $pO_2$ and $pCO_2$ in Expired Gases and to Control the Operation of Respirators

**Nature of Contribution:** It was suggested that fluidic techniques developed at the Harry Diamond Laboratories might be useful in the solution of this problem.

**Evaluation:** A meeting was arranged with members of the Biomedical Group at Harry Diamond Laboratories at which time the problem was discussed. The result of the discussion was the conclusion that an extensive equipment development program would be required to determine the feasibility of using these techniques in this application.

**Plans for Use:** None.

# APPENDIX D

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Steinberg, W. H., F. A. Mina, P. G. Pick, and G. H. Frey, "Heidelberg Capsule 1. In Vitro Evaluation of a New Instrument for Measuring Intragastric pH,"Journal of Pharmaceutical Sciences, May 1965, Vol. 54, No. 5, pp. 772-776.

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Beckman Blood Gas Measurement System
Spinco SB-1600

Chemtronics, Inc., Gas Analysis Equipment

Instrumentation Associates, Inc.
Harris $O_2$ Micro Electrode and $O_2(PO_2)$ Micro Electrode

Yellow Springs Instrument Co., Inc.
Oxygen Instruments

# APPENDIX E

# ABBREVIATIONS

## ABBREVIATIONS

The abbreviations used in the body of the report are identified below:

| | |
|---|---|
| ARC | Ames Research Center<br>Mountain View, California |
| cm | cemtimeter |
| DU | Duke University Medical Center<br>Durham, North Carolina |
| HSS | Hospital for Special Surgery<br>New York, New York |
| Hz | cycles per second |
| IRM | Institute of Rehabilitation Medicine<br>New York, New York |
| LRC | Lewis Research Center<br>Cleveland, Ohio |
| mm | millimeter |
| MRI | Midwest Research Institute<br>Kansas City, Missouri |
| NASA | National Aeronautics and Space Administration<br>Washington, D. C. |
| NCSTRC | North Carolina Science and Technology Research Center<br>Research Triangle Park, North Carolina |
| NCSU | North Carolina State University<br>Raleigh, North Carolina |
| NIH | National Institutes of Health<br>Bethesda, Maryland |
| psi | pounds per square inch |
| RTI | Research Triangle Institute<br>Research Triangle Park, North Carolina |
| SwRI | Southwest Research Institute<br>San Antonio, Texas |
| UNC | University of North Carolina Medical School<br>Chapel Hill, North Carolina |
| UNCD | University of North Carolina Dental School<br>Chapel Hill, North Carolina |
| WF | Wake Forest University, Bowman Gray School of Medicine<br>Winston Salem, North Carolina |